Developing Predictive Measures of Sensorimotor Adaptability to Produce Customized Countermeasure Prescriptions

Completed Technology Project (2012 - 2016)

Project Introduction

Astronauts experience sensorimotor disturbances during the initial exposure to microgravity and during the readaptation phase following a return to an Earth-gravitational environment. These alterations may lead to disruption in the ability to perform mission critical functional tasks required during these gravitational transitions. Astronauts show significant inter-subject variation in adaptive capability following gravitational transitions. The ability to predict the manner and degree to which each individual astronaut will be affected would improve the effectiveness of a countermeasure comprised of a training program designed to enhance sensorimotor adaptability. Therefore the goal of this project was to develop a set of predictive measures capable of identifying individual differences in sensorimotor adaptability to aid in the design of sensorimotor adaptability training countermeasures that are customized for each crewmember's individual sensory bias and adaptive capacity. To achieve these goals we pursued the following specific aims: Specific Aim 1: Determine whether behavioral metrics of individual sensory bias predicts strategic responses and sensorimotor adaptability to novel sensory environments. Specific Aim 2: Develop predictors of strategic responses and sensorimotor adaptability using brain structural and functional metrics. Specific Aim 3: Determine whether specific genetic polymorphisms are associated with individual differences in strategic responses and sensorimotor adaptability to novel sensory environments. Subjects performed behavioral tests that delineated individual sensory bias in tests of visual, vestibular, and proprioceptive function. Subjects were also tested for individual differences in brain white matter integrity (using diffusion tensor imaging, or DTI), functional network integrity (using resting state functional connectivity MRI), and functional MRI activation associated with sensorimotor adaptation task performance. We also determined whether specific genotypes were associated with individual differences in sensorimotor adaptability. Three distinct motor learning tests were used to characterize individual behavioral strategic responses and motor learning capability. The Locomotor Balance Test characterized the strategic initial locomotor responses to a novel walking environment. The Adaptive Functional Mobility Test (AFMT) and the Adaptive Manual Control Test represented tasks producing plastic-adaptive response to a novel sensory environment. Subjects performed these tests to determine if behavioral, neuroimaging and genetic metrics predicted individual strategic and motor learning capability. Behavioral metrics related to proprioceptive function, visual dependency, and sensory integration served as the best predictors of individual strategic and motor learning capability. Behavioral results indicated that performance and adaptability are specific to the environment being tested. This study explored relationships between behavioral parameters and performance on three different types of adaptation tasks. Each task had a different combination of significant parameters and no single parameter was significant for all three motor learning tasks. Diffusion Tensor Imaging (DTI) is an MRI technique used to assess white matter quality in the brain. The DTI results indicated that white matter microstructural

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integrity plays a role in how well individuals are able to respond to novel sensorimotor disturbances. Importantly, the white matter integrity of the corpus callosum was associated with enhanced performance suggesting that intact inter-hemispheric connectivity is an important factor for optimal responsiveness to novel changes in the sensory environment. Resting state functional connectivity MRI (fcMRI) was used to investigate individual differences in large-scale brain networks. These results demonstrated that specific patterns of functional connectivity between resting state networks involved in motor control and cognition are associated with individual differences in sensorimotor adaptation. The fMRI results indicated that a variety of frontal, temporal, and cingulate cortical and subcortical areas in which activation was predictive of individual differences in adaptability during a manual adaptation task. This suggests that some people might be more proficient at recruiting neural areas that allow for efficient adaptation learning. We determined whether genotypes for COMT, DRD2, BDNF, and Alpha 2 adrenergic receptor (DraI) single nucleotide polymorphisms (SNPs) were associated with individual differences in strategic responses and sensorimotor adaptability to novel sensory environments. The DraI and COMT SNPs showed a trend towards distinguishing subjects who exhibit faster or slower responses and adaptation rates on two locomotor tasks. These findings were limited by small sample size, but show promising initial results that may be improved upon by collecting more subject data. In conclusion this study revealed that behavioral, neuroimaging, and genetic metrics can predict individual responses to novel sensory environments and motor learning capability. Predictive power may be enhanced using composite measures composed of a mix of behavioral, neuroimaging, and genetic metrics. Further investigations with astronauts in actual spaceflight conditions will serve to further validate potential predictive metrics of adaptability. These results have important implications for adaptation training programs that facilitate astronaut adaptation to novel environments and for rehabilitation. Specifically, the prospect of identifying people who will likely have difficulty with sensorimotor adaptation would allow for more targeted training programs.

Anticipated Benefits

Sensorimotor adaptability training programs have Earthbound application in rehabilitation of patients with balance disorders, and for fall prevention training among seniors. We have previously shown that training using variation in visual flow during treadmill exercise improves functional mobility in healthy older adults who were experiencing age-related postural instabilities (Buccello-Stout et al. 2008; 2013). Personalized medicine has become an important research topic. Many brain stimulation, physical therapy, and pharmacological approaches to movement disorders are efficacious for some individuals but not others. The ability to predict ahead of time which patients would be most responsive to differing types of treatments would clearly save time and costs, and increase patients' quality of life by providing targeted rehabilitation interventions targeted at individual sensory biases and ability to

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Organization:

National Space Biomedical Research Institute (NSBRI)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Principal Investigator:

Jacob J Bloomberg

Co-Investigators:

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Brian T Peters
Rachael Seidler
Regina R Buccello-stout

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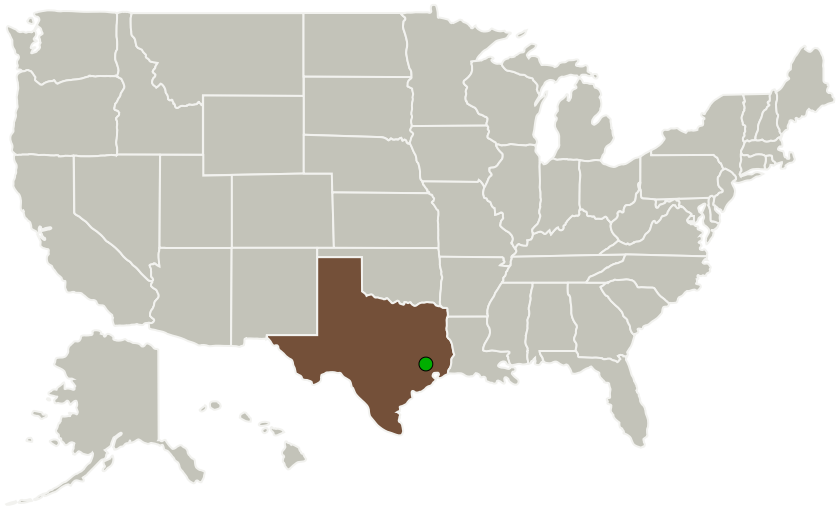
process sensory information. Buccello-Stout, RR, Bloomberg, JJ, Cohen, HS, Whorton, EB, Weaver, GD, & Cromwell, RL. Effects of sensorimotor adaptation training on functional mobility in older adults. J Gerontol B Psychol Sci Soc Sci. 63(5): 295-300. 2008. Buccello-Stout RR, Cromwell RL, Bloomberg JJ, Whorton EB. Effects of sensorimotor adaptation training on head stability movement control in response to a lateral perturbation in older adults. The Journal of Aging and Physical Activity. 21: 272-289. 2013.

Primary U.S. Work Locations and Key Partners

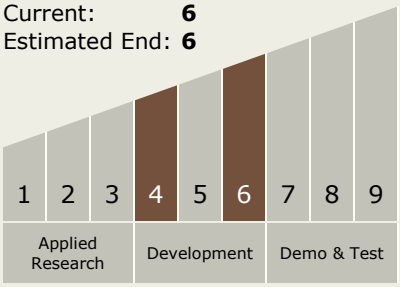


Organizations Performing Work	Role	Type	Location
National Space Biomedical Research Institute(NSBRI)	Lead Organization	Industry	Houston, Texas
Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas

Primary U.S. Work Locations
Texas

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - TX06.3 Human Health and Performance
    - TX06.3.2 Prevention and Countermeasures

Target Destinations

The Moon, Mars

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Project Transitions

October 2012: Project Start

May 2016: Closed out

Closeout Summary: In an effort to increase efficiency and maximize the predictive power of our measures we collected da ta for Specific Aims 1 and 2 simultaneously on the same subjects. This involved behavioral testing in our labs at NASA/John son Space Center and neuroimaging at the University of Texas Medical Branch Victory Lakes Facility, which is located offsit e. This approach had a number of benefits including increased data capture. By having the same subject perform both speci fic aims we were able to enhance our ability to detect how a wider range factors and their groupings can predict adaptabilit y in a specific individual. This provides a much richer data base and potentially a better understanding of the predictive pow er of the selected factors. Dr. Mulavara is currently conducting a complementary National Space Biomedical Research Instit ute (NSBRI) study titled Developing Personalized Countermeasures for Sensorimotor Adaptability: A Bed Rest Study. This st udy will recall subjects who participated in the recent bed rest CFT70 campaign and spaceflight subjects (Functional Task Te st) to investigate if predictive metrics based on behavioral, brain, and genetic markers can be used to retrospectively predic t sensorimotor adaptability in post bed rest and spaceflight subjects. To aid this effort and to develop a complete set of pre dictive metrics we added several new behavioral measures. We also added genetic tests previously used to detect sensorim otor adaptability as possible metrics of adaptability. We called back our original subjects and tested them on these new met rics, which were added to the original set of potential predictive metrics obtained previously. During this reporting period da ta collection analysis was completed. Data Collection at Azusa Pacific University (APU): The focus of the data collection at D r. Wood's APU laboratory was to expand the set of behavioral predictive measures capable of identifying individual differenc es in the ability to adapt to novel discordant sensory environments. In the APU study the inter-subject variability during ada ption to visual distortion lenses was measured in 27 subjects over 3 sessions. During this reporting period data collection a nalysis for the studies at APU was completed. During this reporting period the following manuscripts were published: Seidle r RD, Mulavara AP, Bloomberg JJ, Peters BT. Individual predictors of sensorimotor adaptability. Front. Syst. Neurosci. 9:10 0. doi: 10.3389/fnsys.2015.00100, 2015. Bloomberg JJ, Peters BT, Cohen HS and Mulavara AP. Enhancing astronaut perfor mance using sensorimotor adaptability training. Front. Syst. Neurosci. 9:129.doi: 10.3389/fnsys.2015.00129, 2015. In addi tion, during this reporting period 17 presentations at meetings were completed. See also Bibliography section below.

Stories

Abstracts for Journals and Proceedings
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Project Website:

https://taskbook.nasaprs.com